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High Voltage Transformers

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HIGH VOLTAGE TRANSFORMERS

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GENERAL ELECTRIC COMPANY
SCHENECTADY, N. Y.
OCTOBER, 1918

Second Edition

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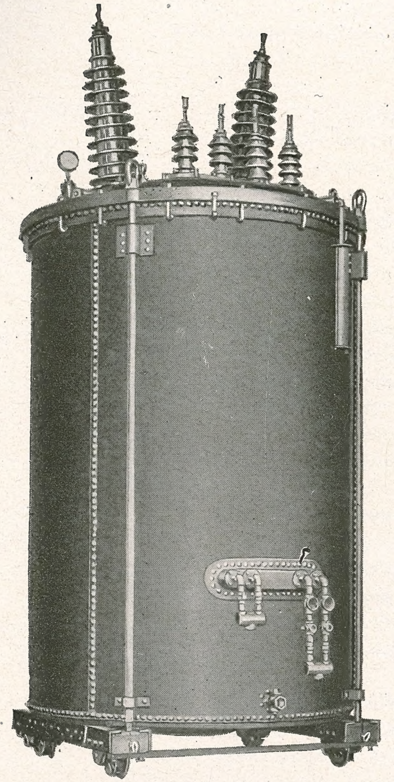

Fig. 1. SINGLE-PHASE, WATER-COOLED, OUTDOOR TRANSFORMER USING ROUND TANK WITH TIGHT-FITTING COVER

HIGH VOLTAGE TRANSFORMERS

SHIPMENT

Transformers are shipped completely assembled in their tanks and filled with oil when size and transportation facilities permit. In most cases, high voltage bushings are removed and shipped separately.

When transformers are shipped filled with oil, special instructions covering features incident to this method of shipping are attached to the transformer and their requirements should be carefully observed.

Because of its height, a transformer may sometimes be shipped completely assembled but lying on its side. In this case, internal blocking is necessary and every piece (MARKED WITH A RED CROSS) must be removed before the transformer is put into service. Attached to transformers shipped in this manner will be found a caution tag giving the above information.

Pressboard barriers are sometimes installed between high voltage and low voltage terminals and between high voltage terminals and cooling coil. These barriers may be shipped disassembled, in which case a red tag is attached to the transformer, calling attention to the fact. Drawings and installing instructions are also attached to the transformer. Additional information, if necessary, may be obtained by applying to the nearest office of the General Electric Company. Such a request should be accompanied with the rating and serial number of the transformer for which instructions are required.

STORAGE

When transformers must be stored before being put into service they should be kept in a dry place, having no rapid or radical temperature changes, and if possible immersed in dry Transil oil. Transformers should not be stored or operated in the presence of corrosive gases, such as chlorine, etc. If stored OUTDOORS they should be thoroughly covered to keep out rain, and made airtight except for breathing through calcium chloride. or, if this is not convenient, transformers should be kept warm. When transformers can be set up immediately in their permanent location it is advisable to do so.

Moisture is almost sure to accumulate in an idle transformer due to the fact that the temperature of any large metallic body will often be markedly below the atmospheric temperature. This can be largely avoided by employing a tight-fitting cover, but the internal atmosphere—especially if no oil is in the transformers—may contain sufficient moisture to do harm if concentrated by condensation on vital parts of the insulation. A chloride breather is the most desirable preventive inasmuch as it prevents any appreciable internal vacuum and insures a dry internal atmosphere. Chloride breathers must be kept well supplied with new chloride of calcium (half inch lumps or

larger) as that originally supplied dissolves. The frequency with which new chloride needs to be added will depend upon the changes in temperature and the humidity of the atmosphere. Only anhydrous chloride of calcium should be used.

When such a breather is not available, the accumulation of moisture may be avoided by storage in a slightly warm room of uniform temperature or by the use of a small electric heater within the transformer.

Before final installation, examine thoroughly for moisture or mildew.

Never put voltage on a unit after continued idleness (spare) without knowing that the oil is in proper condition.

UNPACKING

When necessary to ship transformers with the core and coils dismantled, a factory expert should supervise the assembly. If such expert supervision is impracticable, detailed instructions will be furnished, and all parts (which are tagged) should be assembled exactly according to drawing.

HANDLING

Different types are outlined as follows:

RECTANGULAR COIL CONSTRUCTION

This type of transformer construction is illustrated in Figs. 1 and 2.

Core and coils are equipped with lifting lugs or hooks on the core clamps.

Tanks are either round or rectangular and are lifted with long bolts extending down to the truck (Fig. 1) for handling the complete transformer. The covers are fitted with small eyebolts for handling the cover alone.

Covers for oil-cooled transformers support only the bushings. Covers for water-cooled transformers support bushings and sometimes the cooling coils.

Oil-cooled rectangular coil transformers in round tanks have light cover construction and should be handled by means of the large eyebolts which project through the cover and extend down to the truck.

Water-cooled rectangular coil transformers in oval tanks are provided with two sets of eyebolts on top of cover and are similar to oil-cooled rectangular coil transformers with respect to lifting. The large bolts extend down to the base of the transformer and should be used when lifting the complete unit. The lighter eyebolts are for removing core and coils from the tank, but the long bolts must be removed first. **Hooks on the sides of this tank are for lifting the tank and oil only.**

Old style water-cooled and self-cooled rectangular coil transformers in oval tanks have heavy high-domed covers which are strong enough to support the weight of the complete unit and should be

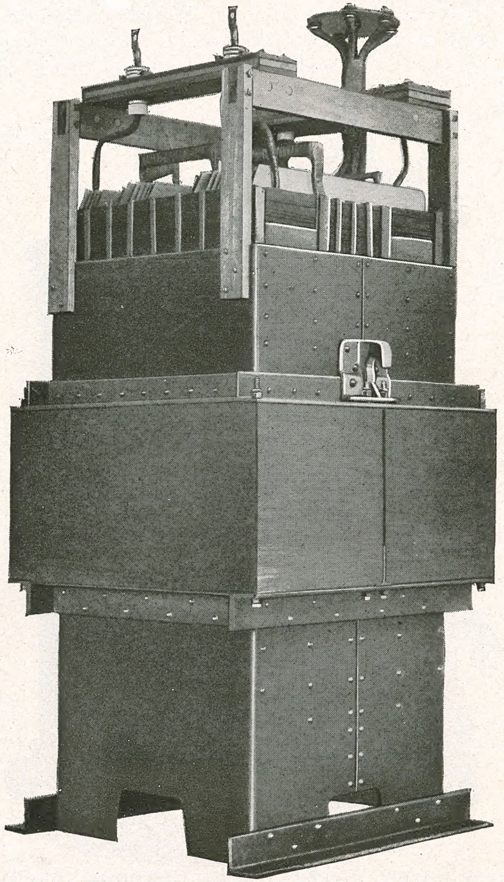

Fig. 2. SINGLE-PHASE RECTANGULAR COIL CONSTRUCTION REMOVED FROM TANK

lifted by the heavy lugs cast in the cover. The hooks riveted to the tanks of transformers of this construction are only for lifting tank and oil, and **are not strong enough to lift the complete transformer.**

CAUTION

When lifting with eyebolts, or hooks riveted to the tanks, the lifting chain or rope should be held apart by a spreader. When rollers

are used the transformer must be placed upon skids to distribute the stress over the base.

CIRCULAR COIL (CORE TYPE) TRANSFORMER

Circular coil transformers may be placed in round or oval tanks as shown in Figs. 3, 4, 5, 6, 7, and 8.

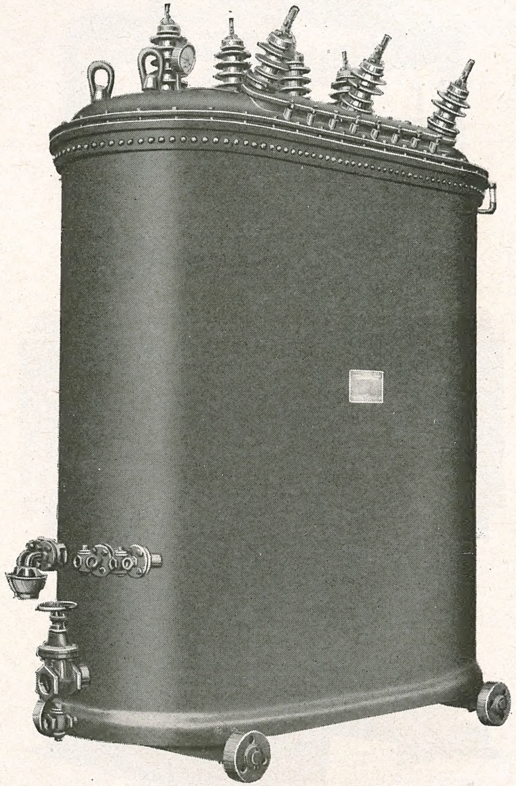

Fig. 3. THREE-PHASE, WATER-COOLED, OUTDOOR CIRCULAR COIL TRANSFORMER, USING OVAL ALL WELDED STEEL PLATE TANK WITH TIGHT-FITTING COVER

The internal construction of the circular coil designs for both water-cooled and self-cooled are similar, differing only in the outward appearance.

The complete transformer in oval tanks is lifted by long bolts extending from the top of the core through the cover with eye nuts on the outside. Figs. 5, 6, 11, and 12.

When hooks are provided on the cover they are for lifting the cover alone. See Figs. 5 and 11.

On the smaller round tanks hooks on the tanks are for lifting the complete transformer. See Figs. 4, 7 and 8.

The larger round tanks for circular coil transformers are provided with long bolts for lifting, similar to the rectangular coil type as shown in Fig. 1.

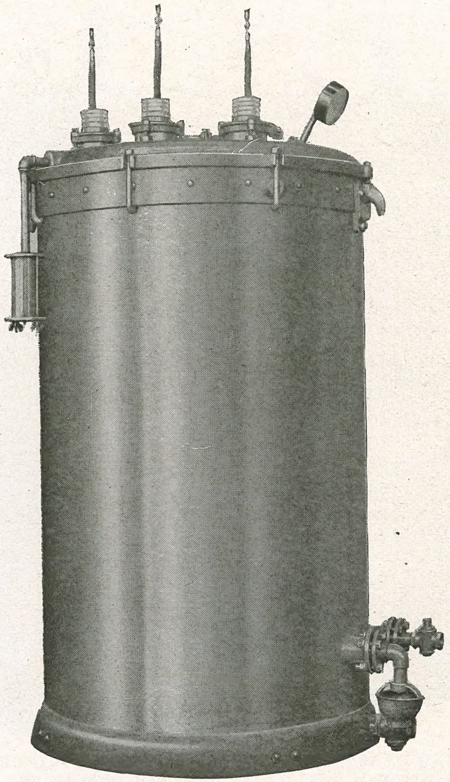

Fig. 4. SINGLE-PHASE, WATER-COOLED, INDOOR CIRCULAR COIL TRANSFORMER, USING ROUND ALL WELDED STEEL PLATE TANK WITH TIGHT-FITTING COVER

INSTALLATION

FOUNDATION

No special foundation is necessary for the permanent installation of large transformers, except a good even floor strong enough to support the weight.

INSPECTION AND CLEANING

Transformers shipped in their tanks should be inspected and cleaned as carefully as possible. All dirt and dust should be wiped off. Castings, porcelains, and high voltage bushings should be examined for breakage or other injury, and repairs made if necessary. All

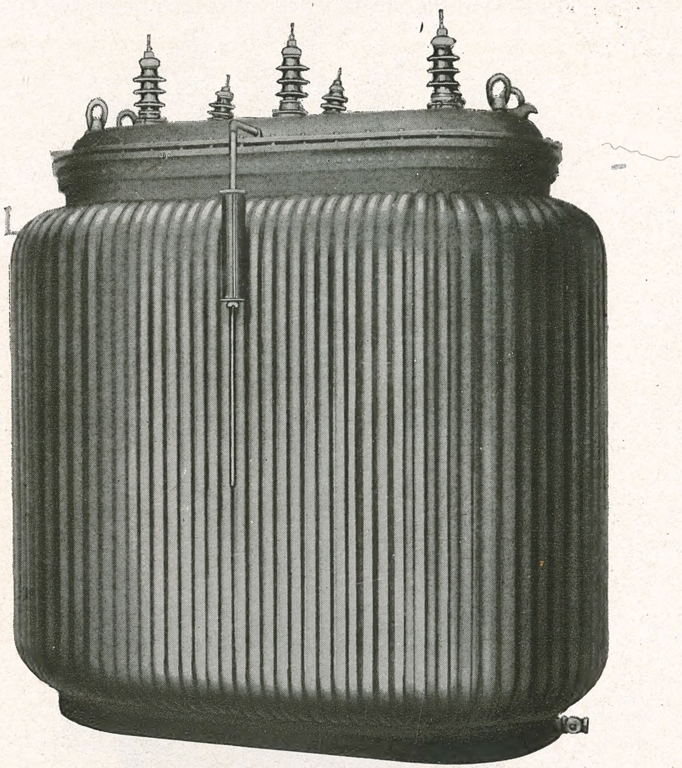

Fig. 5. THREE-PHASE, SELF-COOLED, OUTDOOR CIRCULAR COIL TRANSFORMER, USING OVAL ALL WELDED STEEL PLATE TUBULAR TANK WITH TIGHT-FITTING COVER

conductors throughout their length to the connection board and all terminals on the connection board should be examined to check the proper condition and position. Coil clamps should securely hold the coils. Tighten core clamps, if necessary.

Tanks should be inspected and cleaned if necessary.

If coils and insulation are very dirty they must be washed with *clean, dry* Transil oil under pressure (25 to 50 lb. per sq. in.).

COOLING COILS

Cooling coils should be inspected and tested at a pressure of 80 to 100 lb. per sq. in.

Water, oil, or air may be used in the coil for obtaining the pressure. Coil must be outside of tank, i.e., away from the insulation, if water is used for the pressure test.

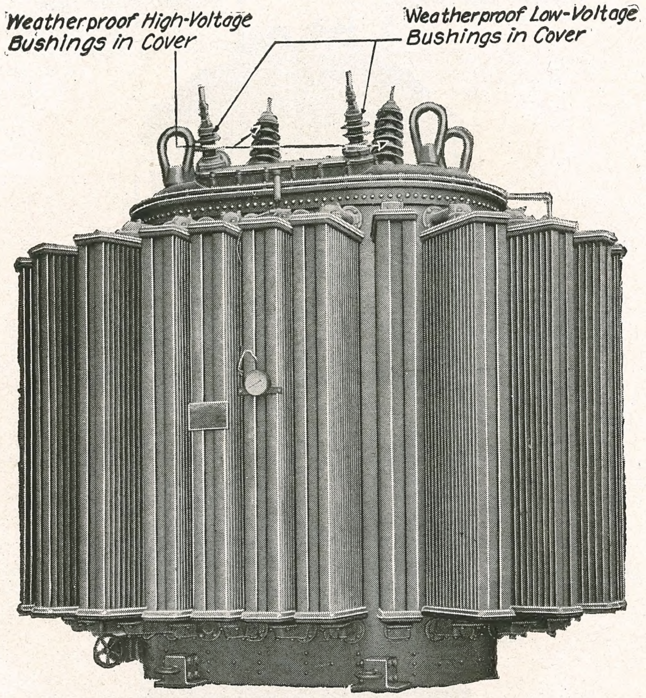

Fig. 6. SINGLE-PHASE, SELF-COOLED, OUTDOOR CIRCULAR COIL TRANSFORMER, USING ALL WELDED STEEL PLATE TANK WITH TIGHT-FITTING COVER, AND SEPARABLE ALL WELDED RADIATORS

When pressure is obtained disconnect supply, and after one hour determine whether any fall in pressure is due to a leak in the coil or in the fittings at ends of coil.

DRYING

All transformers shipped assembled but not filled with oil should be carefully inspected for evidence of moisture or mildew. A thorough inspection can be made only by removing the core and coils from the

tank. If removal from the tank is impracticable, as thorough an inspection as possible must be made through the manholes and bushing outlets. Moisture can usually be detected by signs of rust or sweating on any of the following parts, transformer covers, extension bolts, ter-

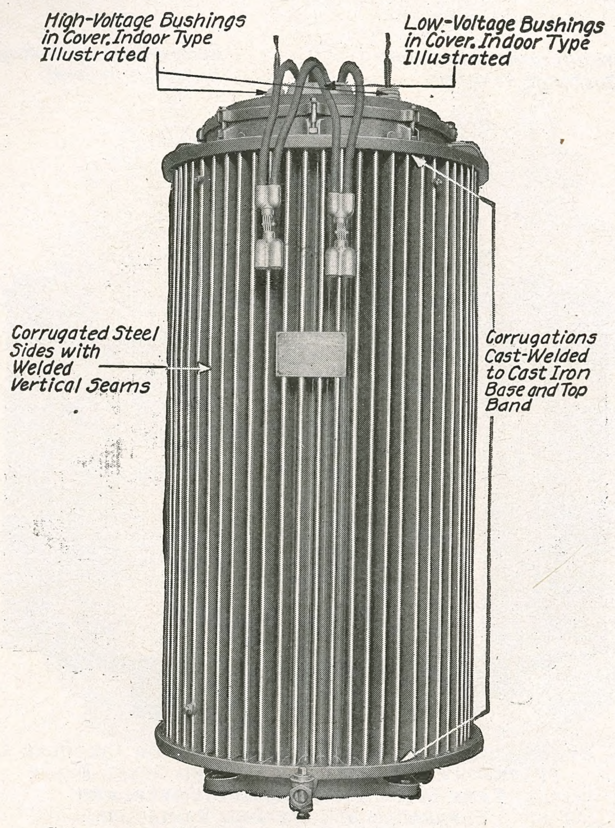

Fig. 7. SINGLE-PHASE, SELF-COOLED, INDOOR CIRCULAR COIL TRANSFORMER, USING ROUND CORRUGATED STREEL TANK WITH TIGHT-FITTING COVER

minal boards, tanks, core clamps, or cores. Mildew should be looked for on the pressboard or varnished insulation.

Transformers of 5000 kv-a. and above must be dried out before installation unless permission to omit drying is obtained from the Transformer Engineering Department.

Transformers of 60,000 volts and above must be dried out before installation unless permission to omit drying is obtained from the Transformer Engineering Department.

Transformers of less than 5000 kv-a. having a voltage between 45,000 and 60,000 volts should be dried out if three weeks have elapsed

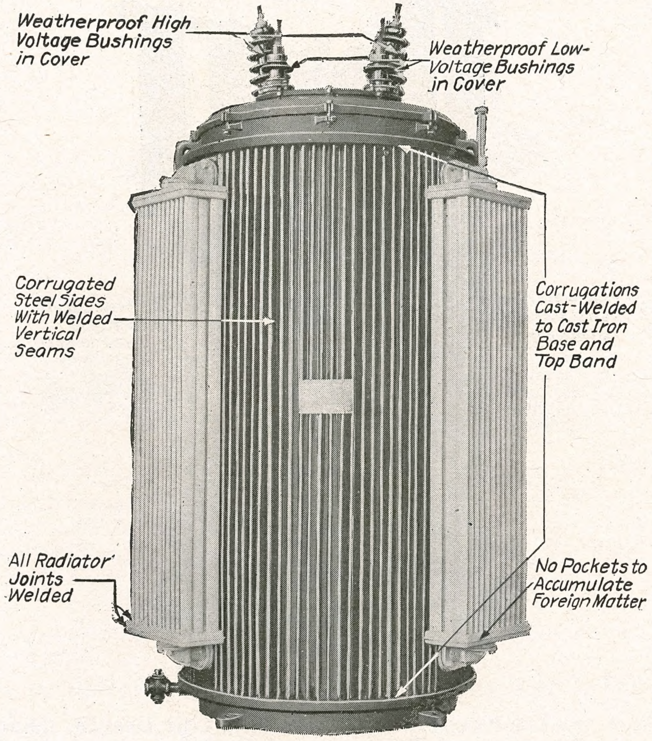

Fig. 8. SINGLE-PHASE, SELF-COOLED, OUTDOOR CIRCULAR COIL TRANSFORMER, USING ROUND CORRUGATED STEEL TANK WITH TIGHT-FITTING COVER AND SEPARABLE ALL WELDED RADIATOR

between date of shipment and date of installation, unless permission to omit drying is obtained from the Transformer Engineering Department.

Transformers of less than 5000 kv-a. and less than 45,000 volts need not be dried out if there are no signs of moisture evident. (See preceding paragraph and also page 5 under Storage.)

Transformers shipped filled with oil must have sample tested from the top and bottom after the transformer has stood for 24 hours. The dielectric strength of the oil must be 22-kv. with 1-in. disks spaced 0.1 in. apart, or 40-kv. with ½-in. disks spaced 0.2 in. apart.

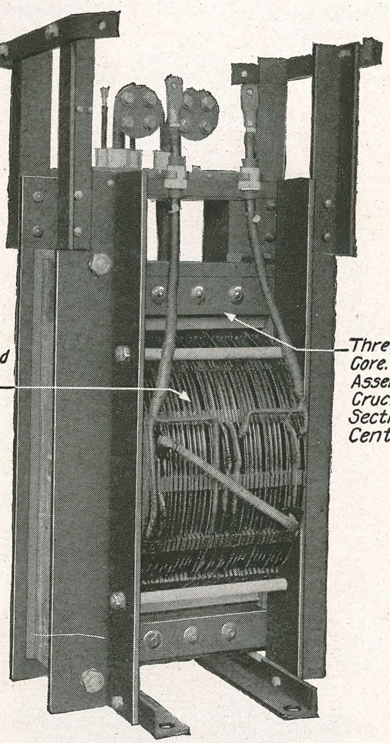

Fig. 9. Single-phase Interleaved Disk Coil Design, Using Three-legged Core

When dielectric strength of the oil in a transformer has decreased 25 per cent from the above value it should be treated.

When oil is shipped in drums it must have a dielectric strength of 22-kv. with 1-in. disks spaced 0.1 in. apart, or 40-kv. with ½-in. disks spaced 0.2 in. apart before being put into the transformer.

Where evidence of moisture is found, transformers must be dried as follows: Force clean, dry air at a temperature of 85 deg. C. into coils and insulation at the *bottom* of the transformer allowing same to

escape at the top. Quantity of air should be such that the temperature of escaping air is approximately the same as the ingoing temperature. Various pipes and deflectors may have to be used to properly distribute the air. Do not let oil run from the transformer into the heater as it may cause a serious fire. The approximate quantity of air to give good results with different size tanks is as follows:

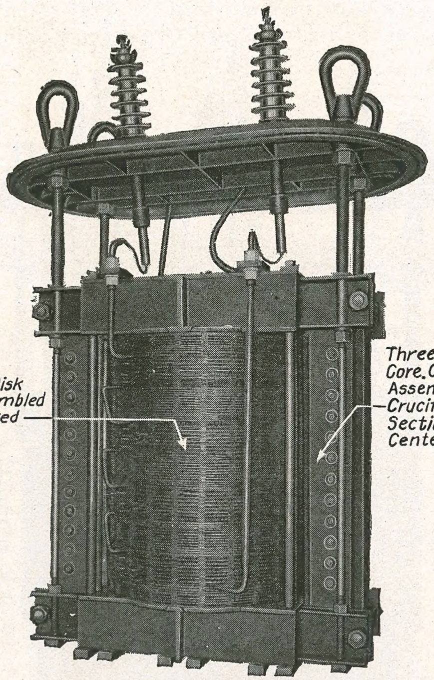

Fig. 10. Single-phase, Interleaved Disk Coil Design, Using Three-legged Core

Diam. in In. or Equivalent Area of Tank	Cu. Ft. Air per Min.
54 to 72 inclusive	600
78 to 96 inclusive	900
102 to 120 inclusive	1200
126 to 144 inclusive	1500
150 to 168 inclusive	1800

In case it is impossible to apply the Hot Air Method for drying, the Short Circuit Method may be applied in the following manner:

Remove the transformer from the tank and place spirit thermometers in direct contact with the high voltage coils (it may be necessary to open up the outside of pressboard casing to do this). These thermometers should be in such a position that they can be easily read and will not be broken. If necessary the transformer may be surrounded with canvas to insure uniform heating in different parts.

One of the windings should then be short-circuited and a low-voltage alternating current applied to the other winding. The current

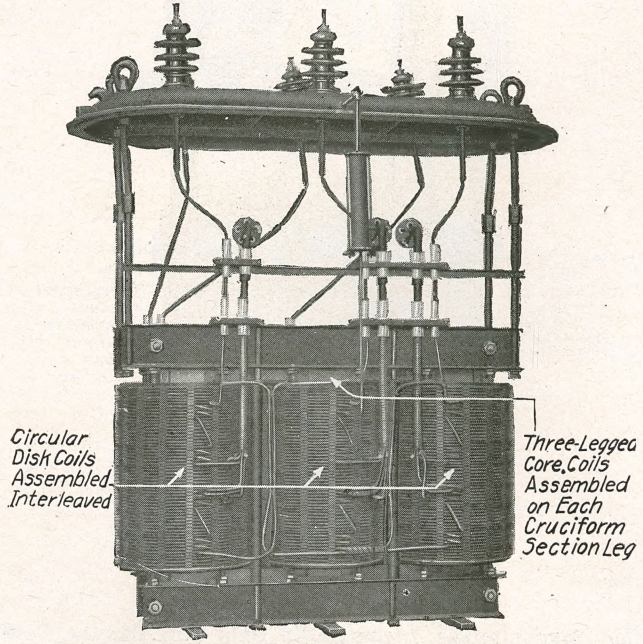

Fig. 11. THREE-PHASE, INTERLEAVED DISK COIL DESIGN, USING THREE-LEGGED CORE

should be such as to give an actual coil temperature of 70 deg. C. and the amount of current required to do this will vary from $1/5$ to $1/3$ of normal full load. In applying this method the thermometer should be constantly watched, applying a very low current at the start and increasing very slowly until the 70 degrees is reached, after which the duration of the drying run will depend upon the voltage, capacity and condition of the transformer.

It is recommended that all transformers be removed from the tank as described above but if this is impossible or highly impracticable the average temperature of the coils may be calculated by the rise in resistance method, leaving the transformer in the tank and the manhole cover open but protected from dirt or moisture. This should not be done, however, unless proper facilities for making these measurements and the services of a man competent to take charge of same are available.

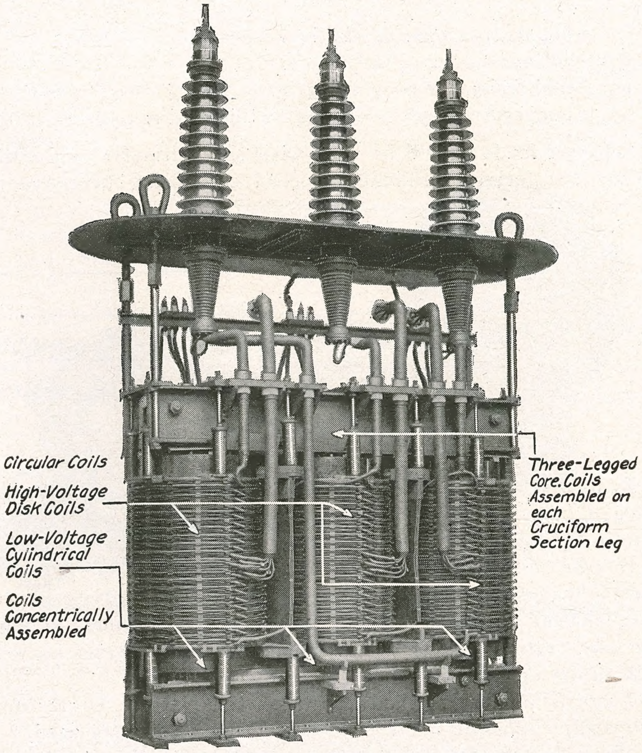

Fig. 12. THREE-PHASE DISK CYLINDER, COIL DESIGN, USING THREE-LEGGED CORE

Very careful measurements of initial (cold) temperatures should be made at the time of measuring the initial (cold) resistances. Connections for making these measurements are shown in sketch, Fig. 13.

These measurements will require the use of a direct-current low reading voltmeter (milli-voltmeter with resistance box preferred), as well as direct-current ammeter. The current used for making the resistance measurements should never be more than 1/5 of the full

load current of the transformer. The following formulae may be used for calculating the temperature of the winding.

$$t_H = \frac{R_H\ (238 \times t_C)}{R_C} - 238$$

where

t_H = hot temperature of winding.
R_H = hot resistance
R_C = cold resistance of winding
t_C = temperature corresponding to this cold resistance.

Separate leads should be used with the voltmeter and attached close to transformer terminals,* special care being taken to make good connections with every reading taken.

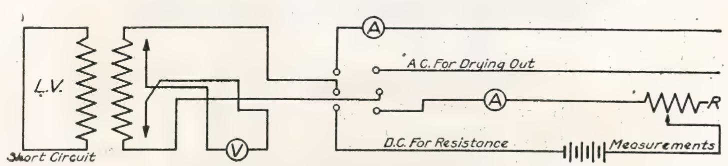

Fig. 13

Readings of resistances should be taken every hour until the 70 deg. C. (actual temperature) has been reached and the load to maintain this temperature determined.

In case this method is used, we would suggest reference to the nearest office of the General Electric Company for advice as to the proper current necessary for any particular transformer, giving the name plate rating and serial number of the transformer as well as details of drying facilities.

There is another method known as the Natural Draft Method which is also applicable if the Forced Air Drying cannot be used.

To apply this method the transformer should be removed from the tank and placed at a sufficient height on the floor so that resistance grids may be placed under the transformer. Extreme care should be used in the choice of grids and the temperature at which they will run, because oil will be dripping from the transformer and may catch fire if the grids are run too hot. In general it will take from 15- to 25-kw. loss in the resistance to successfully dry a moderate size transformer and, as previously mentioned, the grids should be run

* These leads should be attached to terminals only while taking resistance measurements.

at a comparatively low temperature and thermometers (recording thermometers are preferable) placed between the transformer and the grids so that the maximum temperature can be read. The maximum temperature of the air between the grids and the transformer should not be over 90 degrees.

Megger Readings

While the insulation resistance of a transformer cannot be relied upon as a sure indication of its condition at any one time, the general trend of megger readings as a drying run proceeds is a fairly accurate indication of the progress of drying. The drying process should be continued until the curve becomes approximately flat at an elevation

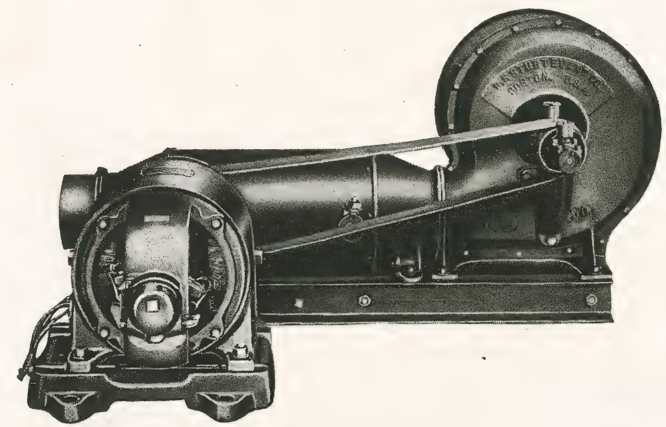

Fig. 14. Hot Air Drying Outfit for Drying Transformers

considerably above the low point of the curve. Variation in temperatures causes wide variation in resistance, the values varying inversely.

If the megger shows a short circuit, that is, an insulation resistance too low to be read, it is very likely due to an excessive amount of moisture. Low readings also sometimes indicate the presence of moist spots in the insulation. Widely different megger readings may be obtained on different transformers, but average readings should be approximately alike for transformers of the same capacity and design.

DRYING OIL AND FILLING TRANSFORMER

Transformers should be operated only in the oil furnished with them.

Oil, whether shipped in sealed barrels or in special tank cars direct from the manufacturer, may require drying at its destination before it is suitable for use in high voltage transformers. All oil should

be tested before using, but, if it is absolutely necessary to use a part of the oil from barrels before tests can be made, the barrels should be allowed to settle for several hours and then the oil pumped from the top to within 4 inches of the bottom; i.e., do not use the oil which settles in the bottom until it can be tested and dried if necessary. Oil drums should be stored lying on their sides.

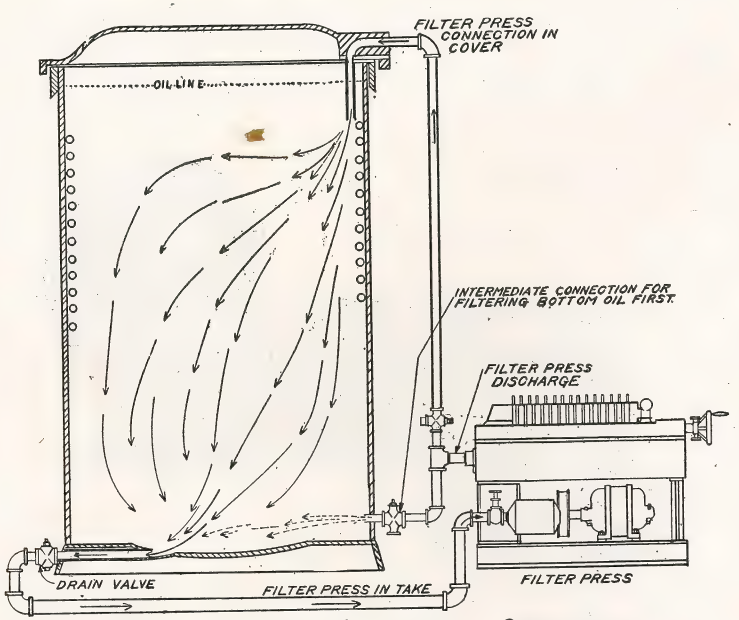

Fig. 15. OIL DRYING APPARATUS IN OPERATION

The General Electric Company has developed and recommends the transformer oil dryer and filter as being the best apparatus for drying and filtering transformer oil. The oil is treated in a filter press, by being forced through several layers of blotting paper, which removes all moisture and solid matter held in suspension in the oil. By this method from 350 to 1200 gallons of oil, according to the size of press, can be treated in an hour. For additional information see instruction book "Transformer Oil Dryer and Filter."

Before the transformer is filled with oil, all accessories such as the valve, gauges, thermometer, plugs, etc., must be fitted to the transformer and made oil tight. The transformer must be thoroughly cleaned as directed under "Inspecting and Cleaning."

Oil may be pumped through the filter directly into the transformer, unless tests on the oil indicate that water is present, in which case the bottom portion of the oil should be drained off from the tank or drums into a separate container and treated separately, because the filter will only handle the small quantity of water which may be held in suspension in the oil. Remove water from oil by settling, drawing off lower portion, and filtering, successively; repeat if necessary. When oil tests satisfactorily but is not run through the filter press, it should be strained through two or more thicknesses of muslin or other closely woven cotton cloth. The straining cloths should be renewed as often

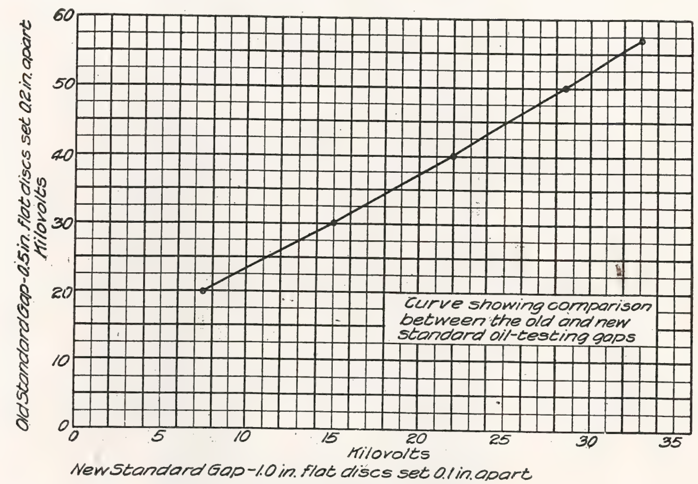

Fig. 16

as necessary, not less than one set of cloths being used for each transformer.

Metal hose is preferable to rubber hose because oil dissolves the sulphur and therefore may decompose the rubber, causing trouble by the sulphur attacking the copper.

After filling the transformer the oil should be allowed to settle at least 12 hours and then samples from top and bottom should be tested before voltage is applied to the transformers.

Occasionally it may be convenient to fill a transformer by forcing the oil from the oil reservoir or treating tank into the transformers by means of compressed air. If this method is used, great care should be taken to make sure no condensed water is blown into the oil and also that all air bubbles are out of oil before transformer is put in service.

Tanks are provided with three openings for filter press connections. One at the extreme bottom (drain valve), an intermediate about six inches from the base, a third in the cover.

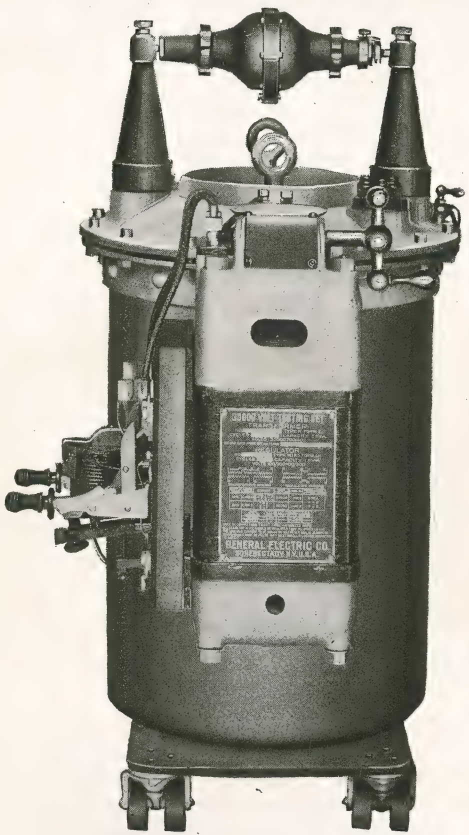

Fig. 17. Oil Testing Set

Samples of oil should be drawn off from the bottom (drain valve) and if any free water is present it should be drawn off before starting the filter.

The intake to the filter press should be connected to bottom opening (drain valve) and the discharge from the filter press to the intermediate connection about six inches from the base. The oil should be circulated through the filter press until the dielectric strength of the oil is of the required value.

It may be necessary to renew the blotting paper quite frequently when operating in this positon.

The discharge from the filter press may then be changed from the intermediate connection to the one in the cover; and the oil circulated continuously if necessary or desirable.

The intake to the filter press remains on the bottom opening (drain valve) throughout the entire filtering operation.

Sampling and Testing Oil

Sample bottles or cans must be thoroughly cleaned and dried before using. It is satisfactory to rinse very thoroughly with clean, dry oil and allow the receptacle to drain for a few minutes.

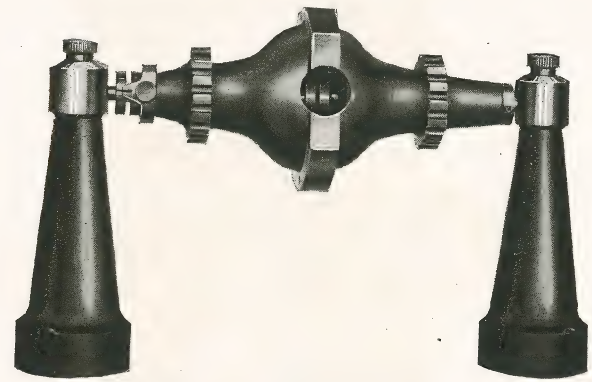

Fig. 18. Oil Testing Spark Gap

Test samples should be taken only after the oil has settled for some time, varying from eight hours for a barrel to several days for a larger transformer. Cold oil is much slower in settling and may hardly settle at all. Oil samples from barrels should be taken about ½ in. from the bottom of the drum. A brass or glass "thief" can be conveniently used for this purpose. The same method should be used for cleaning the "thief" as is used for the container.

The oil testing spark gap should be cleaned in the same manner; simply rinsing with clean, dry oil being the best method to use. The new standard oil testing spark gap has disk terminals 1.0 in. in diameter, which should be adjusted 0.1 in. apart by means of the gauge furnished with the spark gap. The old standard gap has disk terminals 0.5 in. in diameter, set 0.2 in. apart. For purposes of comparison the curve in Fig. 16 is given. The spark gap receptacle should be

nearly filled with oil and allowed to stand for a moment to give bubbles time to escape, especially if the oil is cold.

The rate of increase of voltage should be as fast as can be accurately read on the voltmeter. The total time of application of voltage, from 0 to breakdown value, will usually be about 5 seconds. The average voltage of five tests is usually taken as the dielectric strength of the oil.

An outfit especially designed for testing oil is described in a bulletin entitled "Oil-testing Sets," and may be obtained from the nearest office of the General Electric Company.

In case a regular oil testing outfit is not available, a 22,000-volt potential transformer may be used, with an improvised water rheostat in the low voltage side for regulating the voltage.

If no facilities are available for making dielectric tests, send samples to the nearest office of the General Electric Company or to the Transformer Department, Pittsfield Works. Attach tag to each sample, giving serial number of transformer or barrel from which sample was taken.

When drawing samples of oil from the bottom of transformers or large tanks, several quarts should be drawn off into a glass receptacle before taking the sample for test. A glass receptacle is specified so that if water is present it may be readily observed and measured. If water is found an investigation of the cause should be made and a remedy applied. If water is not present in the first quart or so of oil which is drawn out, it will only be necessary to draw off sufficient oil to flush out the valve, piping, etc.

The best way to clean and dry oil drums is to rinse them very thoroughly with 5 or 10 gallons of gasolene, benzine, or dry transformer oil. The rinsing operation should be repeated several times using fresh liquid each time and draining the drums very thoroughly after each rinsing.

When a testing equipment is not available the best method of testing is to draw off a sample of oil in a high, narrow glass container and allow it to settle for several hours, after which it should be inverted and carefully watched. Any water that is in the oil will slowly settle down to the bottom end. This will apply only if the oil is sufficiently clear and clean so that the water, if present, may be seen. Oil that contains sediment so that this test cannot be made, should not be used.

HIGH VOLTAGE BUSHINGS

Bushings furnished with G-E transformers are of two distinct types, solid bushings and filled bushings. Solid bushings are supplied for voltages of 73,000 volts and below; filled bushings for higher voltages.

Solid Bushing—Type S

Solid bushings are of three classes, Tubular—Form G, Rigid Conductor—Form C, and Cable Conductor—Form F.

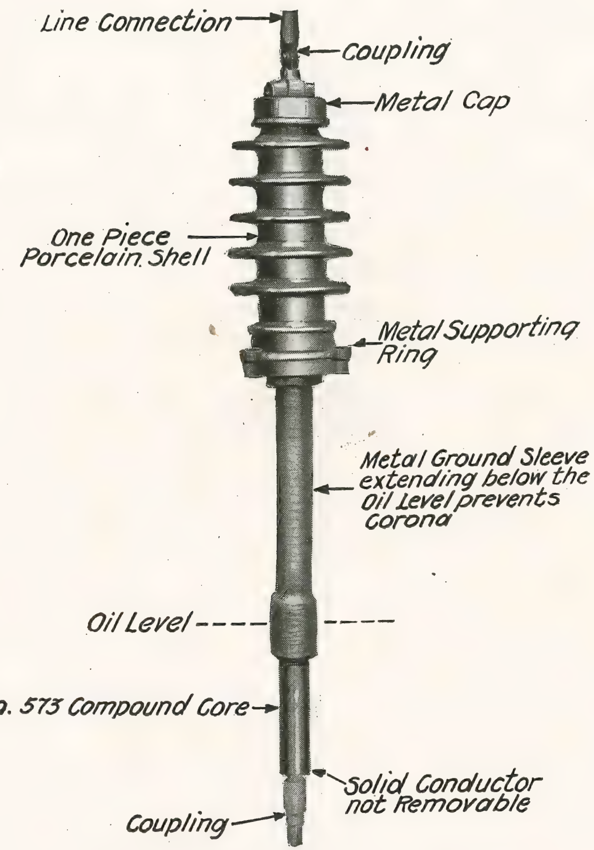

Fig. 19. SOLID RIGID CONDUCTOR TYPE BUSHING

These bushings when received will be ready for installing. They should be kept dry and clean.

(1) TUBULAR bushings are used for voltages of 7501 to 73,000 inclusive, when the current is 250 amperes and below. A cable conductor which passes through the center tube is detachable at the top,

thus permitting the bushing to be removed and replaced without disturbing the internal connections. See Fig. 20.

(2) RIGID CONDUCTOR bushings are supplied for currents exceeding 250 amperes for voltages 7501 to 73,000, inclusive, and are similar to

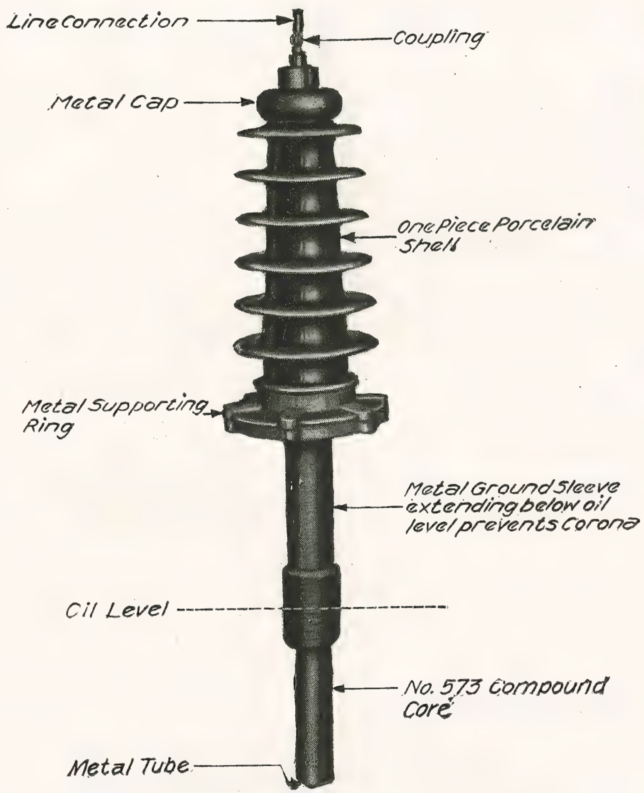

Fig. 20. SOLID TYPE TUBULAR BUSHING—FLEXIBLE CONDUCTOR

the tubular bushings except that they have terminal couplings at the ends of the conducting rod, and cannot be removed from the cover without disconnecting the terminal on the under side of the cover from the transformer windings. See Fig. 19.

(3) FLEXIBLE CABLE CONDUCTOR bushings are supplied for voltages of 7500 and below and like the rigid conductor bushings cannot be removed without disconnecting the lower terminal from the winding on the under side of the cover. See Fig. 21.

Filled Bushings—Types CF and OF

Filled bushings are of two classes, compound filled Type CF, Form B, and oil filled Type OF, Form B.

Filled bushings are used for voltages above 73,000, and are made of two one-piece petticoated porcelain cones separated by a metallic

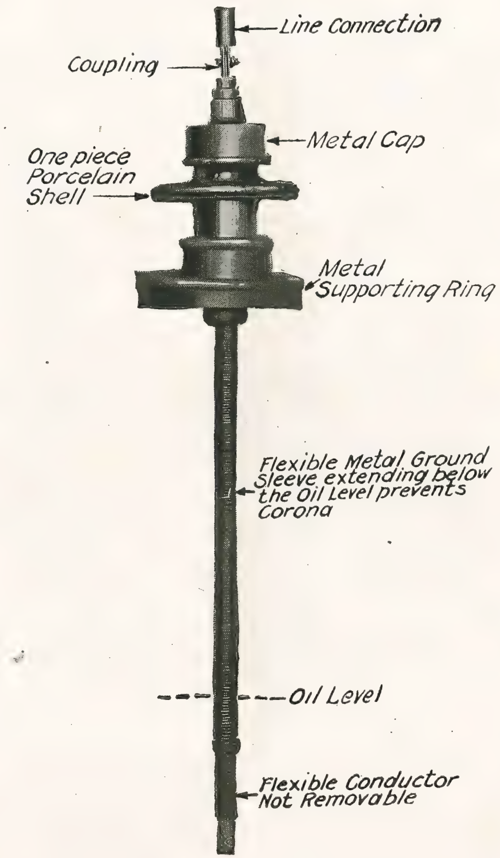

Fig. 21. SOLID CABLE CONDUCTOR TYPE BUSHING

sleeve extending below the surface of the transformer oil, thereby preventing corona in the air space above the oil. The porcelains are bolted to the sleeve by metal clamping rings cemented to the porcelain. See Fig. 22.

These bushings require filling with an insulating fluid as specified on the caution plate attached to the support. No other material should be used. The proper level of cold fluid is indicated on the glass expansion chamber.

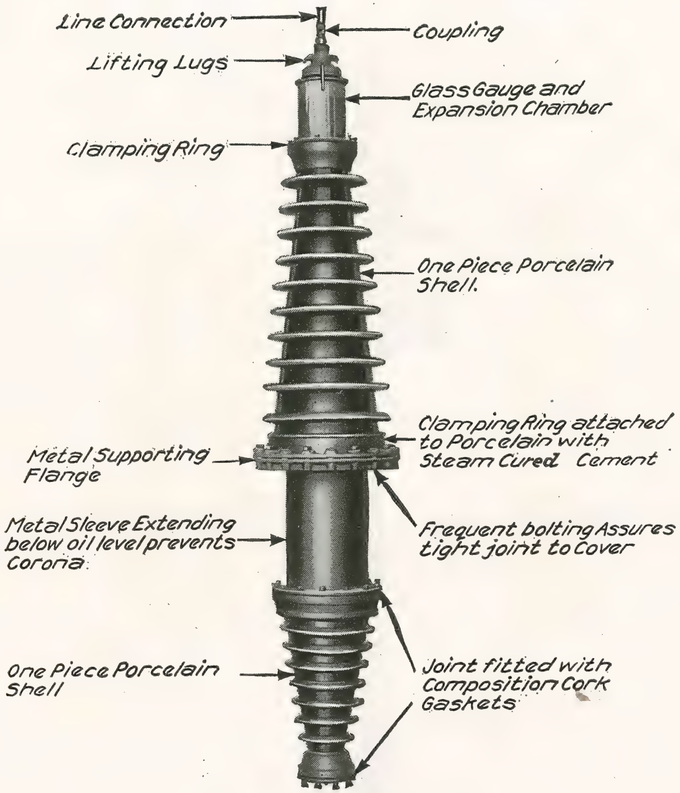

Fig. 22. **Filled Bushing**

Compound filled bushings will generally be shipped filled with compound ready for installing.

Oil filled bushings will generally be shipped empty, accompanied by proper quantities of oil for filling the bushings when installed. The drain plug in the bottom casting should be examined, and if loose it should be tightened before filling the bushing. The oil should be put into the bushing through the slotted casting above the glass chamber after removing the lifting hook.

Handling Bushings

Lifting hooks are provided at the top which should be used in handling the bushings.

Connection

Connection from the transformer windings is made with a flexible cable passing through the center tube of the bushing and connected to the top of the bushing. If the bushing is to be removed from the cover, the flexible cable passing through the center tube should be disconnected from the top before attempting to remove the bushing.

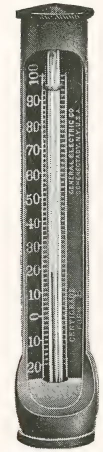

Fig. 23. **Form B Thermometer for Oil Self-cooled Transformers**

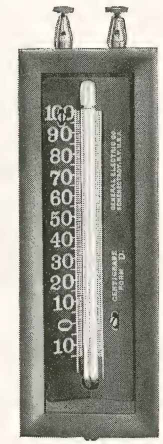

Fig. 24. **Form D Thermometer with Alarm Connections at 80 Deg. for Oil Self-cooled Transformers**

Gaskets

See paragraph on gaskets for instruction on installing bushing in transformer covers.

THERMOMETERS

It is the practice of the General Electric Company to furnish thermometers for all oil-cooled transformers above 200 kv-a., and for all water-cooled transformers 1000 kv-a. and above, and for all combination self-cooled and water-cooled transformers. Thermometers for self-cooled transformers are attached to the side of the tank, near the top, so that the bulb extends into the hottest oil.

Thermometers for water-cooled transformers are mounted on the tank just above the name plate. The capillary tube passes through the cover on a transformer having lifting stud in the cover, and through the tank band on other types. On a transformer with lifting studs through the cover, before removing the transformer from its tank the thermometer dial should be detached from the tank and placed on top of the cover; on other types the cover may be removed without

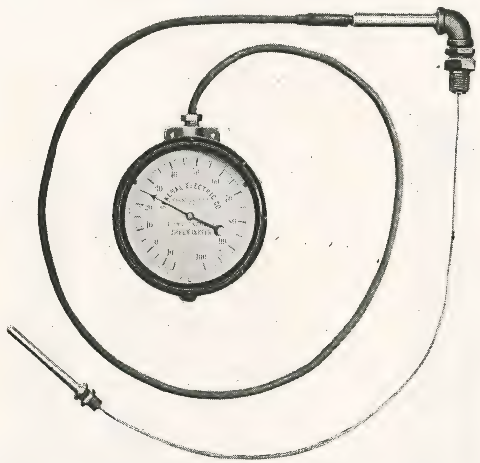

Fig. 25. **Form L Thermometer for Water-cooled Transformers**

disturbing either the transformer or thermometer, but if the transformer is to be lifted out of its tank the thermometer bulb should be removed before attempting to take the transformer out of its tank.

A bulb at the end of a long capillary tube (both being filled with mercury) is mounted just under the oil and therefore indicates the hottest oil, the expansion and contraction of the mercury being transmitted to the pointer by means of a rack and pinion. The extra length of tubing must be carefully fastened out of the way of bushings and connections.

If read frequently, thermometers will indicate any unusual conditions affecting the transformers. They must not be relied on, however, as an indication of permissible loads, because the difference between coil and oil temperature varies widely in different designs and under different load conditions as further noted under "Operating Transformer."

GASKETS

Joints between tank and cover, manhole cover and tank cover, bushing holders and cover are supplied with suitable gaskets. When

installing these gaskets, care must be taken to see that they are in such condition that no leaks will occur after clamping in place.

Joints in asbestos, felt, and other similar gaskets should be "scarfed," while with lead-covered rubber "butt" joints are used, the lead being soldered; the rubber and the lead joints should be "off-set" an inch or so. This off-set can be made by cutting off 1 inch of lead covering from the rubber at one end and stretching out the rubber 1 inch and cutting off at the other end, then put the two ends together and solder the lead, making a continuous gasket.

Felt can be used only once, but the other materials may be used more than once. Felt and asbestos should be soaked an hour or more in varnish (shipped with transformer) and then left to dry over night in a warm room.

PIPE CONNECTIONS

The transformer having been filled with oil, the cooling coil ends should be connected to the water system. Water should not be taken from any place where large quantities of air are likely to be mixed with it, because superfluous air in water greatly increases the rapidity of oxidation in iron cooling coils.

Stuffing boxes around the cooling coils must be properly packed with a cork gasket supplied. The cork gasket should be soaked in the varnish supplied before being used. If cork gaskets are not available ¼-in. asbestos rope soaked in litharge and glycerine (three parts litharge, one part glycerine) may be used. Old type transformers should have Portland cement (mixed "neat") poured around cooling coil outlets. Water-cooled circular-coil type transformers and some rectangular-coil type transformers have the cooling coil ends brought out below the oil level. If such transformers are received empty, the stuffing boxes must be packed, in manner described above, and allowed to "set" one day before filling the tank with oil.

Oil valves should be connected to permanent piping to facilitate emptying the transformer.

CONNECTIONS

Regardless of the floor or foundation on which a transformer sets, the tank should be permanently and effectively grounded.

NAME PLATE RATING

When the transformer has a complicated series of voltages and especially where a great variety of taps are required by the design, they are usually given on the name plate. In cases where they are not, complete information in regard to the various combinations will be found on the D. S. sketch mounted on the transformers.

SWITCHES AND FUSES

Moderate size transformers of comparatively high voltage have in the past been installed in three-phase circuits with single-phase disconnecting switches for putting the transformer on and off the line. This is now considered an undesirable practice on account of the induced voltage between secondary and ground should the high voltage disconnecting switches be closed one at a time. Three-pole (three-phase) air break switches should be used and fuses in the high voltage side should be very much larger in proportion to those in the low voltage side, as high voltage fuses should only be used to relieve short circuits rather than to prevent overload.

CONNECTING IN MULTIPLE

When desiring to multiple transformers that are not of identically the same design, communicate with the nearest Sales Office which has access to the design records maintained by the Transformer Engineering Department at the factory. If it is not convenient to do this, great care should be exercised in determining that the polarity and ratios of transformers to be multipled are the same. When paralleling transformers for the first time, at operating voltage, they should be fused lightly, and all load discontinued during the test. After the transformers are under load, the division of total current should be tested. Reactors may be necessary to correct the division of load.

OPEN DELTA OPERATION

When necessary to operate a three-phase shell type transformer open delta, due to a damaged winding, etc., care should be taken to see that both primary and secondary windings of the damaged phase are not only disconnected, but also short circuited upon themselves. Otherwise further damage may result.

Unless the damaged phase be removed from the iron, or each turn in each coil open circuited, three-phase core type transformers can not be operated with two phases in open delta. The delta connection must be used on both high and low voltage sides. When operated with a damaged winding open circuited, the damaged phase is subject to very high voltages at high frequency and should be removed from the core if possible. If it is not possible to remove it from the core the coils should be disconnected from each other so that there would be no considerable turns in series. This is especially necessary where the voltage is greater than 44,000.

CARE

The idea that transformers in service need no attention may lead to serious results.

Artificially cooled transformers should not be run continuously, even at no load, without the cooling medium. Therefore, it is essential to maintain a proper circulation of the cooling system.

COOLING WATER

If the water circulation of water-cooled transformers is for any reason stopped, the load should be immediately reduced as much as possible, and a close watch kept on the temperature. Reduce the load when the oil at the top, near the center of the tank, approaches 80 deg. C. **This temperature shold be recognized as an absolute limit and must not be exceeded.** It should be held only during an emergency period of short duration.

The ingoing cooling water should never have a maximum temperature of over 25 deg. C.

Nearly all cooling water will in time cause scale or sediment to form in the cooling coils. The time required to clog up a coil depends on the nature and amount of foreign matter in the water. The clogging materially decreases the efficiency of the coil and is indicated by a high oil temperature and a decreased flow of water, load conditions and water pressure remaining the same.

The most frequent cause of clogging of iron cooling coils is a large quantity of air in the water resulting in the formation of a scaly oxide.

REMOVING SCALE FROM COOLING COILS

Scale and sediment can be removed from cooling coils without removing the coils from the tank. Both inlet and outlet pipes should be disconnected from the water system and temporarily piped to a point a number of feet away from the transformer, where the coil can be filled and emptied safely. Especial care must be taken to prevent any acid, dirt, or water from getting into the transformer.

Blow or siphon all the water from the cooling coil and then force into the coil a solution of hydrochloric acid, specific gravity 1.10. (Equal parts of concentrated hydrochloric (muriatic) acid and commercially pure water will give this specific gravity.)*

After the solution has stood in the coils about an hour, flush out thoroughly with clean water. If all the scale is not removed the first time, repeat until the coil is clean, using new solution each time. The number of times it is necessary to repeat the process will depend on the condition of the coil, though ordinarily one or two fillings will be sufficient.

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* It has been found necessary in several cases to force this solution into the cooling coils and when this has been done one end of the coil has been partially restricted so that the solution will not be wasted when the coil is full.

The chemical action which takes place is very noticeable and often forces acid, sediment, etc., from both ends of the coils; therefore it is well to leave both ends open to prevent abnormal pressure.

When water-cooled transformers have operated for some time, especially if the operating temperatures are high, the oil may leave a deposit on the *outside* surface of the cooling coils. Any deposit decreases the efficiency of the coils and should be removed. This condition of the coils is indicated by higher oil temperature, water flow and load conditions remaining the same. The coil should be examined whenever indications point to the formation of a deposit.

DRAINAGE OF COOLING COILS

Cooling coils with the ends through the cover *will not drain under any conditions.* To remove the water they should be blown out with air under pressure from 10 to 100 lb. per sq. in.

Cooling coils with both ends through the tank near the bottom, or with one end near the top and the other near the bottom, *will only partially drain*, even with both ends wide open. To remove the water that remains in the coils they too should be blown out with air under pressure.

IDLE COOLING COILS

When water-cooled transformers are idle and exposed to cold, the water must be blown out of the cooling coils. In addition to blowing out the water the cooling coil should be dried by forcing heated air through it. If not convenient to force heated air through the coil, enough alcohol should be poured into the coil where the ends are brought through the cover to fill the two bottom turns of each section

OIL

During the first month of service of transformers having a potential of 40,000 volts or over, samples of oil should be drawn each week from the bottom of the tank and tested. **Samples from all transformers should be drawn and tested at least once every six months.**

If at any time the oil should puncture below a safe voltage (see limits given on page 13), the filter press may be used for treating it without taking the transformer out of service. Samples of oil should be inspected as described on page 23, under "Sampling and Testing of Oil," and any free water present should be drawn off before starting up the filter press. After removing the water, oil may be drawn into the filter press through the valve in the base, filtered and returned to the transformer through the cover. The discharge pipe should have such fittings as to discharge the oil downward close to the side of the tank and slightly below the surface of the oil. The intake and discharge to and from the filter press should be at diagonally opposite

points in the transformer tank. Circulate the oil until the test is satisfactory.

Storage tanks and piping system for oil should always be cleaned before using. Piping should be so laid out that the entire system can be effectively drained, also the system should be arranged so that oil may be circulated through it by means of the oil dryer and filter and thus relieve the piping of all water or dirty oil.

The oil level in transformers should be kept up to the mark on the oil gauge. On oil-cooled transformers with external cooling pipes or radiators, the oil must be above the top pipes in the tanks or the oil will not circulate and transformer will overheat.

When chloride breathers are provided, only **anhydrous chloride of calcium** in half inch lumps or larger should be used. The frequency with which new chloride may be added will depend on the changes in temperature and the humidity of the atmosphere.

Oil-cooled transformers, occasionally, are operated under conditions of poor ventilation, overload, or over-voltage. Any of these conditions, or a combination of them, may raise the temperature of the oil abnormally high, causing the oil to throw down a deposit which forms on the transformer surfaces. Should the deposit on any surface, except the base, reach an average thickness of about 1/8 in., the oil should be renewed. To determine the thickness, the oil should be drained from the tank and transformer lifted out. Such a deposit does not necessarily mean that the transformer is in immediate danger, but the oil should be renewed as soon as possible. Before putting new oil into the tank the sediment should be removed from all surfaces and the windings cleaned by *forcing dry, clean* Transil oil through all ducts and against all surfaces until all deposit is removed.

TEMPERATURE

Thermometers should be read hourly, and if an oil temperature of 80 deg. C. or over for the self-cooled is indicated, or 65 deg. C. or over for water-cooled, the transformer must be cut out of service at once, and the cause of the excessive heating looked into; for should the transformer remain in service any length of time under this condition it may be seriously damaged.

Regardless of oil temperature as indicated by thermometers, transformers must not be operated at overloads not stipulated by the specifications, or contact. When operating water-cooled transformers at an overload the amount of water should be increased in proportion to the load. On account of the increased amount of water during overload, the temperature of the oil will not rise as fast as the temperature of the windings and any of the causes leading to excessive heating will have more pronounced effect under these conditions.

Therefore, transformers *during overload* should be watched with especial care to see that the oil temperatures are kept well *below* the temperature limits specified.

Compartments in which oil-insulated self-cooled transformers are installed should be thoroughly ventilated. Openings for cool air should be provided at various points near the floor, and outlets should be in or near the roof, which should not be closer than 6 to 10 feet from the top of the transformer. The room temperatures in which transformers are installed should not exceed the temperature of the air entering the room by more than 5 degrees, and presumably, the entering air will come from the outside, or at least, from a source not much warmer than the outside air.

There is practically no danger of condensation of moisture in transformers which have no chloride breathers if the oil at all times is kept 10 degrees or more above the room temperature. It is also desirable, especially in moist climates, to keep the oil in idle transformers (not equipped with breathers) slightly warm in order to eliminate the chance of the oil becoming moist. This may be accomplished by applying voltage alone for a few hours each day. Water-cooled transformers should be watched to see that the oil temperature does not drop below the limits specified, and if it does, the amount of water must be decreased until the oil attains a temperature of at least 10 degrees above the surrounding air.

SUPPLY PARTS

Whenever ordering supply parts or asking for information regarding a particular transformer, the serial number must always be stated. On large transformers this number, in addition to being on the name plate, will be found stamped on the top core frame, the top band of the tank, and also on the cover directly above the number on the tank band.

CONCLUSION

The instructions given in the foregoing pages for the installation and operation of high voltage transformers must necessarily be quite general in their nature. More complete information as to the electrical or mechanical construction, operation, or installation of particular transformers may be obtained by application to the nearest local office of the General Electric Company.

GENERAL ELECTRIC COMPANY

PRINCIPAL OFFICES: SCHENECTADY, N. Y.

SALES OFFICES (Address nearest Office)

Atlanta, Ga.	Third National Bank Building
Baltimore, Md.	Lexington Street Building
Birmingham, Ala.	Brown-Marx Building
Boston, Mass.	84 State Street
Buffalo, N. Y.	Electric Building
Butte, Mont.	Electric Building
Charleston, W. Va.	Charleston National Bank Building
Charlotte, N. C.	Commercial National Bank Building
Chattanooga, Tenn.	James Building
Chicago, Ill.	Monadnock Building
Cincinnati, Ohio	Provident Bank Building
Cleveland, Ohio	Illuminating Building
Columbus, Ohio	The Hartman Building
Dayton, Ohio	Schwind Building
Denver, Colo.	First National Bank Building
Des Moines, Iowa	Hippee Building
Detroit, Mich.	Dime Savings Bank Building
Duluth, Minn.	Fidelity Building
Elmira, N. Y.	Hulett Building
Erie, Pa.	Commerce Building
Fort Wayne, Ind.	1600 Broadway
Hartford, Conn.	Hartford National Bank Building
Indianapolis, Ind.	Traction Terminal Building
Jacksonville, Fla.	Heard National Bank Building
Joplin, Mo.	Miner's Bank Building
Kansas City, Mo.	Dwight Building
Knoxville, Tenn.	Burwell Building
Los Angeles, Cal.	Corporation Building, 724 S. Spring Street
Louisville, Ky.	Starks Building
Memphis, Tenn.	Randolph Building
Milwaukee, Wis.	Public Service Building
Minneapolis, Minn.	410 Third Ave., North
Nashville, Tenn.	Stahlman Building
New Haven, Conn.	Second National Bank Building
New Orleans, La.	Maison-Blanche Building
New York, N. Y.	Equitable Building, 120 Broadway
Niagara Falls, N. Y.	Gluck Building
Omaha, Neb.	Electric Building
Philadelphia, Pa.	Witherspoon Building
Pittsburgh, Pa.	Oliver Building
Portland, Ore.	Electric Building
Providence, R. I.	Turks Head Building
Richmond, Va.	Virginia Railway & Power Building
Rochester, N. Y.	Granite Building
St. Louis, Mo.	Pierce Building
Salt Lake City, Utah	Newhouse Building
San Francisco, Cal.	Rialto Building
Seattle, Wash.	Colman Building
Spokane, Wash.	Paulsen Building
Springfield, Mass.	Massachusetts Mutual Building
Syracuse, N. Y.	Onondaga County Savings Bank Building
Toledo, Ohio	Spitzer Building
Washington, D. C.	Commercial National Bank Building
Worcester, Mass.	State Mutual Building
Youngstown, Ohio	Stambaugh Building

For TEXAS, OKLAHOMA and ARIZONA Business refer to Southwest General Electric Co. (Formerly Hobson Electric Co.)

Dallas, Tex.	Interurban Building
El Paso, Tex.	500 San Francisco Street
Houston, Tex.	Third and Washington Streets
Oklahoma City, Okla.	1 West Grande Ave.

Motor Agencies in all large cities and towns

Partial List of FOREIGN Sales Offices

General Electric Co., Foreign Dept.	Schenectady, N. Y.
General Electric Co., Foreign Dept.	Equitable Bldg., 120 Broadway, New York City
General Electric Co. of N. Y.	83 Cannon St., London, E. C., England
Australian General Electric Co.	Melbourne and Sydney
Companhia General Electric do Brazil	Rio de Janeiro
Cia. General Electric Sudamericana	Buenos Aires
Mexican General Electric Co.	City of Mexico and Guadalajara
South African General Electric Co.	Johannesburg and Cape Town

Representatives and Agents in all countries

For all CANADIAN Business refer to Canadian General Electric Co., Ltd., Toronto, Ont.

High Voltage Transformers